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ESTIMATING THE VALUE OF RISK REDUCTIONS FOR CAR DRIVERS WHEN PEDESTRIANS ARE INVOLVED: A CASE STUDY IN SPAIN

Rosa Marina González*

Instituto Universitario de Desarrollo Regional, Universidad de La Laguna, La Laguna, Spain, rmglzmar@ull.es

Concepción Román

Instituto de Turismo y Desarrollo Económico Sostenible, Universidad de Las Palmas de Gran Canaria,
Las Palmas de Gran Canaria, Spain, croman@daea.ulpgc.es

Francisco Javier Amador

Instituto Universitario de Desarrollo Regional, Universidad de La Laguna, La Laguna, Spain. famador@ull.es

Luis Ignacio Rizzi, Juan de Dios Ortúzar

Departamento de Ingeniería de Transporte y Logística, Centro de Desarrollo Urbano Sustentable (CEDEUS),
Pontificia Universidad Católica de Chile, Santiago, Chile, lir@ing.puc.cl; jos@ing.puc.cl

Raquel Espino, Juan Carlos Martín

Instituto de Turismo y Desarrollo Económico Sostenible, Universidad de Las Palmas de Gran Canaria,
Las Palmas de Gran Canaria, Spain. respino@daea.ulpgc.es, jcmartin@daea.ulpgc.es

Elisabetta Cherchi

Department of Transport, Technical University of Denmark, Copenhagen, Denmark. elich@transport.dtu.dk

ABSTRACT

We estimated the benefits associated with reducing fatal and severe injuries from traffic accidents using a stated choice experiment where choice situations were generated through a statistically efficient design. Specifically, the risk variables were defined as the expected annual number of vehicle car-users that suffered their death or were severely injured in a traffic accident. In addition, and differing from previous research, the number of pedestrians that died or were severely injured in traffic accidents per year was also included as a risk attribute in the choice experiment, to attempt at measuring drivers' willingness to pay to reduce the risk of hitting pedestrians in a crash. The empirical setting was a choice of route for a particular trip that a sample of car drivers periodically undertakes in Tenerife, Spain.

Models were estimated accounting for random taste heterogeneity and pseudo-panel data correlation. The median of the distribution of simulated parameters was used to obtain a representative measure for the monetary valuation of risk reductions. We found that the ratio between the values of reducing the risk of suffering a serious injury and that of reducing a fatality was approximately 18%. Further, and quite novel, we also found that the value of reducing a pedestrian fatality was 39% of the value of reducing a car occupant fatality.

KEYWORDS: value of risk reduction, stated choice experiment, efficient design, willingness to pay, road accidents, pedestrian victims

*Corresponding author. Tel 34-922-317113. Fax: 34-922-317204. Address: Facultad de Economía, Empresa y Turismo. Campus de Guajara. s/n 38071 La Laguna. S/C de Tenerife, Spain.

1 INTRODUCTION

Scarce resources mean that policy makers have to prioritize among different investments towards road safety. One benefit that may accrue from investment projects in the transport sector is a reduction in the number of seriously injured or fatal victims in road accidents; these victims can be car-users or pedestrians. Thus, we need to obtain a monetary valuation for the reductions in risk levels associated with each type of accident. This constitutes a welfare improvement to be added in a cost – benefit analysis of transport projects. Research on these values can help increase the efficiency and equity of transport investment projects.

The monetary valuation of changes in risk levels have been usually obtained from the analysis of exchanges made by individuals regarding small variations in risk levels and money. These exchanges can be observed in real markets (for instance, in the labour market individuals may accept jobs with greater risk in exchange for a better salary) or in hypothetical markets through the use of experimental design techniques. According to microeconomic theory, the value of goods and services is derived from individual choices and, therefore, the loss of welfare to accident victims should be evaluated according to the willingness-to-pay (WTP) of those affected by the reduction in accident risks. This general procedure has been used in WTP studies in several developed countries (Trawen *et al.*, 2002) such as the United Kingdom, Sweden, Norway, the United States and New Zealand. In this study a contemporary application will be adopted following the pioneering work of Rizzi and Ortúzar (2003), with the aim of deriving values for reducing the risks of being any type of victim (fatal or seriously injured) in a road accident when pedestrians are also involved.

If the principle of valuing accident risk reductions from individual preferences is accepted, the next step involves the determination of appropriate values. Many studies in the past used the *contingent valuation* (CV) method in the road accidents context (Jones_Lee *et al.*, 1995; Beattie *et al.*, 1998; Carthy *et al.*, 1999; Hammit and Graham (1999); Persson *et al.*, 2001). More recently, *stated choice experiments* (SCE) have been increasingly employed to estimate such values (De Blaeij *et al.*, 2002; Rizzi and Ortúzar, 2003, 2006a, 2006b; Iragüen and Ortúzar, 2004, Hojman *et al.*, 2005; Hensher *et al.*, 2009; Veisten *et al.*, 2013; Flügel *et al.*, 2015).

The aim of this study was to estimate the benefits associated with reducing fatal and severe injuries from traffic accidents using a SCE administered to drivers of the TF5 highway in Tenerife (Spain). Specifically, the risk variables were defined as the annual number of vehicle car-users that suffered their death or were severely injured in a traffic accident. In addition, and differing

from previous research, the number of pedestrians that died or were severely injured in traffic accidents per year was also included as a risk attribute in the choice experiment, to measure drivers' willingness to pay to reduce the risk of hitting pedestrians in a crash. Although the risk of hitting a pedestrian is a health risk to a third party, there is an associated personal cost involved in this type of events, which takes into account the psychological damage experienced by the vehicle occupants owing to the crash and its consequences; in addition, there are monetary and time-use costs associated with the administrative and legal processes characterising these events. The risk of hitting a pedestrian could also give rise to altruism in respondents (who are drivers themselves) who are taking into account the level of safety of pedestrians *per se*¹.

As our model accounts for random taste heterogeneity, the mean of the simulated distribution was used to compute the corresponding WTP. In order to obtain more robust results, avoiding the effect of possible outliers, the median of the distribution was also used as a representative measure for the monetary valuation of risk reductions. These figures are also compared with the ratio of the estimated means of the random parameters. The estimation of the number of trips, based on traffic counts in different points along the corridor, together with the WTP for reducing the risk of an accident was used to compute the value of risk reductions, also referred to as the value of a statistical life. Our model provides a novel result: drivers would appear to be willing to pay more to reduce the risk of running over a pedestrian causing his/her death or grievous bodily harm, than to reduce their own risk of suffering serious injuries in a traffic accident.

The rest of the paper is organized as follows. In section 2 the experimental design and the main characteristics of the sample are presented. Section 3 describes the methodology used, and explains how accident risk reductions must be monetarily valued under no-rivalry conditions for the population. Section 4 contains our main results and its discussion. Finally, section 5 summarises our main conclusions.

¹ We are explicit in mentioning the level of safety of pedestrians as the cause of altruism instead of the level of welfare. In the former case –paternalistic altruism–, respondents will derive personal utility from knowing that pedestrians walk in a safer road environment; in the latter case –pure or non-paternalistic altruism–, respondents will derive personal utility from any measure aimed at improving the welfare of pedestrian whether this is a road safety improvement or an income transfer. Only if altruism is paternalistic, it will add to the value of safety reduction (Jones Lee, 1992).

2 EXPERIMENTAL DESIGN AND DATA

We designed a SCE in the context of car driving commuters and non-commuters making choices between their current (reference) route and an alternative route with varying travel attributes. The survey was undertaken in Santa Cruz de Tenerife (Spain) in 2010. Santa Cruz de Tenerife was the Spanish province with the largest percentage increase of accident black spots in the period 2003-2007 (Dirección General de Tráfico, DGT) and also the province that experienced the highest growth rate in the number of accidents (229.5%) at the time of the survey. Within the province, TF5 was the road with the largest number of casualties and accidents in 2007 (69 victims and 52 accidents) and with the largest number of accident black spots (12 spots). This evidence led us to think that TF5 could be an appropriate corridor to make our survey since its users should consider safety as an important enough attribute to influence their route choice. Moreover, although walking along TF5 highway is prohibited, there are breaches of pedestrians crossing the highway. In addition, there are some bus-stops without an adequate degree of separation between the stop and the highway. In fact, the local authorities were planning investments to move the bus-stops outside of the TF-5 motorway and, in this way, ensuring greater security, especially of the people who are waiting at the stops. According to statistics from the Spain's Department of Motor Vehicles, seven pedestrians died or were seriously injured between 2006 and 2008.

The main filter for respondents was the requirement to be car drivers travelling through a section of the TF5 at least once a week. A telephone call was used to establish eligible participants from households stratified in terms of sex, age, car ownership and economic activity to guarantee sample representativeness, and to arrange a time and location for a face-to-face computer aided personal interview (CAPI). Participants that could not arrange a personal interview had the opportunity to access a web page questionnaire for a self-completion survey. All respondents received detailed information and explanation about the survey. A major effort and extreme care was also devoted to the field survey. Properly trained economics students at Universidad de La Laguna conducted face-to-face interviews². We closely monitored the survey during the field work and promptly solved and clarified any problems that occurred. To customize the survey Sawtooth SSIWeb 6.6.8 software was used.

We obtained a set of 513 completed survey forms. Several checks were also performed on the data to ensure that all responses where we had doubts regarding quality were removed. Some

² To encourage participation, two laptops computer were raffled among participants; response rate was nearly 60%.

observations, in fact, were rejected due to filling out errors or to some detected inconsistencies. In particular, we found that several web surveys were completed in a very short time (i.e. less than six min); this led us to suspect that these could have been answered haphazardly, even though respondents were asked to answer in a rigorous way and as close as possible to what they would do in the real world. Given that the average survey time took about 15 min, we considered that forms completed in less than a half of that time should be removed. We also eliminated responses by people who did not actually travel by TF5 (zero distance), but only used the highway to access a bridge that leaves it almost immediately again. Thus, the final effective sample size was 477 respondents, comprising 390 CAPI surveys and 87 self-completed web based surveys. Table 1 contains information about the socio-economic characteristic of the sample.

There is a higher proportion of men and the majority of the sample is composed of adults between 18 and 35 years of age. On the other hand, the average respondent had upper secondary or vocational training (42.7%), was an employee (54.5%) with two vehicles in the family and a monthly family income between € 1,000 and € 3,000. However, the information about income must be taken with caution due to the large item nonresponse³ for this query. Notwithstanding, note that the average monthly income in the island (€ 2097 in 2007) is in line with the average reported by our sample (€2255 in 2010) suggesting that this is not formed by purely wealthy people.

To ensure that the sample was representative of car drivers travelling through TF5, given that there was no information available for specific roads, we took as reference the information about the population of car drivers in Tenerife as given in the *Plan Territorial Especial de Ordenación de Transportes de Tenerife 2009* (PTEOTT) (see last column in Table 1). Even though the data are not directly comparable, in general terms, our sample replicates fairly well the characteristics of the car drivers' population in Tenerife, as described in this territorial plan, with the exception of economic activity, where some differences can be observed: while the percentage of people employed and unemployed is very close to that reported in the plan, the number of students is over represented and the number of retired people is much less than the official data. The over-representativeness of students may be explained by the fact that the university is located near this corridor; the under representation of pensioners, on the other hand, was possibly caused by

³ As Yan *et al.* (2010) indicate survey data on personal and household income is usually associated with a large amount of item nonresponse.

the difficulties experienced in finding pensioners that used TF5 as car drivers. Finally, since no information was available on car ownership for the car driver's population in the island, we could not analyze the representativeness of the sample in relation to this feature, although data for the total population in the island are shown in Table 1.

Table 1. Socio-economic characteristics of the sample

Variable	Description	Cases	%	PTEOTT (%)
Sex	Men	265	55.56	60
	Women	212	44.44	40
Age	18-35	245	47.76	30
	36-50	176	34.31	40
	51-65	45	8.77	20
	>65	7	1.36	10
	No response	40	7.8	-
Education	Primary school	36	7.55	-
	Secondary school	19	3.98	-
	Upper secondary or vocational	204	42.77	-
	3-year degree	100	20.96	-
	5-year degree	103	21.59	-
	Post-graduate	12	2.52	-
	No response	3	0.63	-
Occupation	Employee	260	54.51	71.00*
	Self-employed	49	10.27	
	Housekeeper	4	0.84	5.24
	Student	88	18.45	4.35
	Unemployed	42	8.81	9.45
	Retired	12	2.52	9.93
	Employee and student	12	2.52	
	Others	10	2.10	
Trip purpose	Work	205	42.98	53.8
	Education	78	16.35	3.76
	Personal business	31	6.50	8.02
	Others	163	34.17	-
Household's monthly net income	Less than € 1,000	25	5.24	-
	€ 1,001- € 3,000	87	18.24	-
	€ 3,001 - € 5,000	25	5.24	-
	More than € 5,000	6	1.26	-
	No response	334	70.02	-
Number of vehicles per family	1	124	26.00	37.8
	2	237	49.69	31.7
	3	84	17.61	8.8
	>3	30	6.31	4.5
	No response	2	0.42	-

*In the PTEOTT (2009) self-employees and employees appears aggregated.

The risk of having an accident was included through three variables: (i) the number of car-users expected to die per year (fatalities), (ii) the number of car-users expected to be seriously injured per year (i.e. somebody whose condition required hospitalization for more than 24 hours), and (iii) the number of pedestrians expected to die or to be seriously injured per year.

The experimental design was pivoted around a *reference alternative* (Rose *et al.*, 2008), in such a way that attribute levels were adapted to the actual experience of the respondent. This made the final design more realistic as the hypothetical choices became more familiar to respondents, increasing the relevance of the attribute levels in accordance with ideas from *prospect theory* (Tversky and Kahneman, 1981). Thus, all attributes of the unlabelled stated choice alternatives were based on values of the current trip.

In the case of the travel time component, we considered percentage variations over the actual values reported by each traveller during the survey preliminary questions. Travel operating costs (C) were estimated rather than asked directly, as in many cases users only have an approximate idea about them and seldom they are capable of reporting the vehicle maintenance component. To estimate travel costs, respondents were asked about the total length of their reference trips, how much of the time were they exposed to heavy traffic conditions (T_1) and normal or low traffic conditions (T_2), and at what speeds they had driven (S_1 and S_2). This information was used to estimate the distances travelled in each case (D_1 and D_2). Then, vehicle fuel consumption, as a function of speed, was estimated using vehicle fuel consumption charts from the UK Traffic Division for 2008, both for gasoline and diesel engines⁴. The influence of travel cost on route choice was emphasized by also showing respondents the estimated monthly cost associated with the number of trips per month stated by them.

On the other hand, respondents were informed that the levels of the accident risk attributes for the current route corresponded to annual averages based on the official statistics, compiled from Spain's Department of Motor Vehicles (DGT), for the TF-5 highway from 2006 to 2008⁵. Thus, these levels were the same for all TF5 users. In addition, it was suggested to respondents that

⁴ These values were obtained from the following trip operating cost (in euros) expression:

$$C = (Consumption(S_1) \cdot D_1 + Consumption(S_2) \cdot D_2) \cdot P \cdot h + 0.49$$

where consumption is given in litres/km and speed (S) in km/hour. P is the price of fuel, h is a conversion factor that refers to vehicle type and 0.49 represents the estimated fixed cost (insurance, maintenance and taxes) for the reference trip.

⁵ In the case of fatalities, these averages were based on data about casualties within 24 hours after the accident, since disaggregate data on fatalities within 30 days were not available at the time of the survey.

routes with a higher number of injured/dead victims had a greater likelihood of experiencing a road accident and/or suffering serious injuries/dead.

Table 2 shows the attribute levels and percentages used to construct each experimental design. Since all attributes were defined with three levels, respondents were given a total of nine choice situations with the aim of satisfying attribute level balance (i.e., all levels of each attribute were repeated the same number of times in the experiment). A statistically efficient design (i.e. built with the purpose of minimizing the standard errors of the coefficients to be estimated) was used to generate the stated choice questionnaire (Huber and Zwerina, 1996; Kanninen, 2002; Sándor and Wedel, 2001; Rose and Bliemer, 2009). Specifically, we built a design that minimized the D_p -error, which is an efficiency measure that can be used when *a priori* information is available on the value of the parameters (Carlsson and Martinsson, 2002; Huber and Zwerina, 1996).

Table 2. Attributes and levels of the stated choice experiment

A priori parameters	Attributes	Reference values for current route	Alternative route levels		
			0	1	2
-0.25	Operating cost	C	-50%	0%	+50%
-0.1095	Travel time under severe congestion	T ₁	-25%	0%	+50%
-0.058	Travel time for low/moderate congestion	T ₂	-25%	0%	+25%
-0.05	Car-users fatalities per year in route TF-5	5	-2	+0	+2
-0.01	Car-users with severe injuries per year in TF5	32	-10	+0	+10
-0.009	Pedestrian victims per year in route TF-5	3	-1	+0	+1

Initial *a priori* values for the parameters were fixed so that the resultant WTP values were consistent with those obtained at other studies in similar contexts, except for the case of pedestrian victims. The *a priori* value for this parameter was taken as the average of the coefficients for fatalities and severe injuries, since no reference value was available. These priors were improved after estimating models using the pilot sample data. The values finally used to generate the efficient design are shown in the first column of Table 2.

Not knowing in advance the final model specification, we opted to generate an efficient design for a multinomial logit (MNL) model with a linear-in-parameters specification of the utility function. In addition, since it was not possible to have a different design for each respondent, we decided to define three strata as a function of the distance travelled: less than 20 km, between 20 and 40 km

and greater than 40 km. A homogeneous design for each stratum, considering its average reference values, was generated using *Ngene* (ChoiceMetrics, 2010).

The generated choice situations are shown in Appendix 2 and an example of a choice situation as faced by the respondents is given in Figure 1.

Figure 1. Example of stated choice situation*

Suppose you have to make again the trip you described and the following alternative routes are available to you. Which one would you choose?

		Current TF-5 route	Modified TF-5 route
	Travel Cost		
	• For one trip	2,50 €/trip	1,25 €/trip
	• Monthly cost of making <u>5</u> trips/week	50 €/month	25 €/month
	Travel time under severe congestion	20 min	20 min
	Travel time under moderate congestion or free flow	10 min	7,5 min
	Car-users fatalities per year	5	2
	Car-users with severe injuries per year	32	42
	Pedestrian fatalities or seriously injured per year	3	4
		○	○

* The text was translated to English from the original Spanish version.

Since the 477 effective respondents faced nine choice situations each, a total of 4,291 observations was finally available for model estimation⁶. Table 3 shows the main descriptive statistics associated with the current trip as reported by the respondents. The attribute levels for

⁶ If the travel time under congested conditions was zero in choice situation 4, the current route dominated the alternative. The presence of this scenario enabled us to assess whether respondents travelling outside the severe congestion period answered consistently. The analysis of responses showed that almost all individuals responded consistently in this scenario, with only two drivers choosing the dominated alternative. We decided to remove these two inconsistent responses reducing the total number of observations to 4,291 for the model estimation stage.

the current trip were used to characterize the reference alternative scenarios during the experimental design.

Table 3. Descriptive analysis of attribute levels for reference alternative

Variables	Sample mean	Std dev.	Min	Max
Travel cost	2.60	1.46	0.72	10.53
Travel time under severe congestion	8.56	13.30	0	70
Travel time under low/moderate congestion	27.36	17.26	0	105
Total travel time	35.92	20.42	5	120
Trips per month	6.78	4.37	1	28

Statistics about potentially lexicographic choice behaviour are given in Table 4. The proportion of people apparently choosing lexicographically one way or another (54.5) seems high, but fairly high numbers have been found in previous studies, including the seminal paper by Rizzi and Ortúzar (2003), and higher proportions (i.e., almost 75% in a 4-set survey) were also found by Sælensminde (2001; 2002) in his seminal study about this issue. Notwithstanding, we cannot be sure if these respondents are truly lexicographic or if they just appear to be so, by answering in this way given the attribute levels shown in the experiment. For this reason, the approach followed in this research was to keep them unless it could clearly be demonstrated that they were indeed captive and had no choice, or were truly lexicographic and did not compensate among attributes (Ortúzar and Willumsen, 2011).

Table 4. Descriptive analysis of potentially lexicographic choice behaviour

	Number of respondents	(%)
Always lowest cost	66	13.84
Always lowest travel time	18	3.77
Always lowest fatalities	111	23.27
Always lowest injuries	64	13.42
Always lowest pedestrian victims	1	0.21
Total	260	54.51

3 THE VALUE OF RISK REDUCTIONS

3.1 Model formulation

Estimates for the value of road accident risk reductions using SCE may be obtained from discrete choice models, the majority of which are based on Random Utility Theory (Domencich and McFadden, 1975; Ortúzar and Willumsen, 2011). The theory postulates that individuals q associate utility to each alternative i in their choice sets (U_{qsi}) and choose the alternative with maximum utility in choice situation s . Utility is viewed as a stochastic variable made up of the sum of two components: the indirect utility function V_{qsi} and a stochastic component ε_{qsi} , such that:

$$U_{qsi} = V_{qsi} + \varepsilon_{qsi} \quad (1)$$

In the SCE individuals faced choices between two hypothetical alternatives for making their trips. The first was the current route and the second was a hypothetical route offering different levels for some attributes, in some cases improvements and in others disadvantages with respect to the current route. As the route choice process forced individuals to face the trade-offs between the various attributes (for instance, the alternative route may be seen as safer, but also more expensive or slower), their choices reveal the subjective valuations of the attributes.

This type of discrete route choice decision can be modelled using a binomial logit model (Ortúzar and Willumsen, 2011) with a linear-in-the-parameters indirect utility function (the choice situation index, s , and the individual index, q , are omitted here to ease notation), such as:

$$V_i = \alpha_{SQ} + \alpha f_i + \beta SI_i + \chi Pe_i + \delta t_i + \gamma c_i \quad (2)$$

where f_i and SI_i denote the number of fatalities and severely injured car-users during the year in that route, respectively; Pe_i is the number of pedestrians ran over who died or were severely injured in the route during the year; c_i is the travel cost and t_i the travel time associated with using the route; α , β , χ , δ and γ are parameters to be estimated and α_{SQ} is an alternative specific constant for the “current situation” or *status quo* (SQ). The addition of α_{SQ} improves model fit by accounting for the average effect on utility of exempt attributes (Adamowicz *et al.*, 1998; Train, 2002); it expresses the utility associated with the SQ alternative relative to the non-SQ alternative, which is not accounted for by the specified attributes.

Furthermore, tastes may vary with characteristics that cannot be observed and for this reason expression (2) can be generalised to consider heterogeneity, by specifying random parameters for each individual. If the taste parameters (β_q) are allowed to vary with density F over the sampled population and we consider an identically and independently Gumbel distribution for the error term (ε_{qsi}), we get a Mixed Logit (ML) random parameters model; further, by allowing the parameters to vary between and not within respondents, the model accounts for the pseudo panel nature of SC type data (Ortúzar and Willumsen, 2011; Train, 2009). In this case, the expected choice probabilities for the model are given by the following expression:

$$E[P_{qsi}] = \int \frac{\exp(V_{qsi})}{\sum_{j \in J_{qs}} \exp(V_{qsj})} F(\beta / b, \theta) d\beta_q \quad (3)$$

where F is a general density function for the parameters and b and θ represent the mean and covariance characterising its distribution.

In a model accounting for the pseudo panel nature of the SCE data, the interest lies in the probabilities of observing the sequence of choices made by each respondent. Thus, the probability P_q^* that a respondent q has made a certain sequences of choices $\{y_{qsi} = 1\}_{s \in S_q}$ with respect to the set of choice situations, S_q , is defined by:

$$P_q^* = \int \prod_{s \in S_q} \prod_{i \in I_{qs}} (P_{qsi})^{y_{qsi}} F(\beta / b, \theta) d\beta \quad (4)$$

This is the probability used in model estimation (Hensher and Greene, 2003; Sillano and Ortúzar, 2005). This process requires simulation over the random parameters and error terms. All models presented in this paper were estimated using BIOGEME (Bierlaire, 2003).

3.2. The values of risk reductions

The *value of a fatal risk reduction* (VFRR) is the sum of the willingness to pay for reducing the expected value of the number of car occupant deaths per time unit over all individuals affected by the death risk. For a given individual q in route M , this marginal willingness to pay (WTP_q^M) is given by the marginal rate of substitution between income (in this model this is equal to minus the cost coefficient) and the number of deaths:

$$WTP_q^M = \frac{\partial V_q / \partial f}{\partial V_q / \partial c|_{V=\bar{V}}} \quad (5)$$

Thus, summing over all individuals affected by the death risk⁷ we get:

$$VFRR = \sum_q \frac{\partial V_q / \partial f}{\partial V_q / \partial c|_{V=\bar{V}}} \quad (6)$$

which is also known as the *value of a statistical life* (Viscusi and Aldry, 2003). Similarly, we can derive expressions for the *value of reducing the risk of being severely injured* (VSRR) and the *value of reducing the risk of killing or severely injuring a pedestrian* (VPRR).

If we assume that $\alpha, \beta, \chi, \delta$ and γ are generic coefficients, and that the total number of respondents is equal to Q (in our case, Q can be interpreted as the annual flow in route TF5), then the expression for the $VFRR$ simplifies to:

$$VFRR = Q \cdot WTP_q^M = Q \cdot \frac{\alpha}{\gamma} \quad (7)$$

and we can proceed similarly to calculate the $VSRR$ and the $VPRR$.

A caveat needs to be introduced about the interpretation of WTP results. We do not know the exact way respondents processed each attribute. In the Introduction, we discussed the fact that the WTP to reduce pedestrian casualties may incorporate an altruistic component. This altruistic component may also apply to the WTP for reducing car-occupant fatalities and severe injuries. An extreme case would be someone who believes her risk of an accident is zero, but is willing to pay to drive on a safer route just for the safety of other people. Even more, all these three WTP values may include two other components: (i) the dread, shock and disgust associated with witnessing the scene of an accident; and (ii) the disruption caused by accidents with casualties. Hence, our estimates of WTP for reducing the number of car occupant casualties and pedestrian casualties should be interpreted as the summation of all these components and not only as the

⁷ The valuation of a fatality reduction involves a risk judgment by drivers. We did not provide respondents with flow estimates allowing them to assess objective risks of being fatally or severely injured. We assumed that people processed risk in a subjective fashion following mechanisms as those suggested by Anscombe and Aumann (1963). For more details about this issue, see Rizzi and Ortúzar (2006a).

willingness to pay for personal safety (even though the instructions of the survey were to concentrate on one's own risk regarding car-occupant casualties).

There is still another warning in interpreting one specific result: the value of reducing pedestrian casualties. As some car drivers may also be pedestrians on this route, the pedestrian risk changes might affect them as pedestrians as well. Although respondents were instructed to respond from the standpoint of drivers, some of them might have considered pedestrian casualties as a different risk accruing to them⁸. If this were the case, this particular estimate may reflect some unknown mix of WTP to reduce risk to one-self and to reduce the risk to others.

4 DISCRETE CHOICE MODELLING

Our first specifications included travel time under severe congestion and under low/moderate congestion with different coefficients. However, we found a fairly similar perception for travelling under any type of congested conditions⁹; for this reason, the different components of total travel time were aggregated and only one coefficient was estimated; all models were specified with generic parameters for all variables.

We first estimated a simple binary logit model (Model 1) imposing homogeneity on population tastes and treating the different observations corresponding to each driver as independent. All coefficients in this model were significant and had the expected sign. As this model can be restrictive, because coefficients are forced to be the same across respondents and the pseudo panel nature of the data is not considered, we estimated models relaxing these assumptions. First, we allowed for a correct treatment of the pseudo-panel nature of our data (i.e. repeated observations per individual), by estimating a *mixed logit* (ML) model considering a *panel effect*; this was simply done by including common error components to all observations from the same individual (Train, 2009) and as individuals faced only two options at each scenario, there are no complications with this procedure. Interestingly, and in contrast with most previous studies, we found that this ML model was not superior to the simple MNL (i.e. the error components had negligible variance).

A second step was to try and detect the presence of systematic heterogeneity in preferences; for this, different specifications were estimated by introducing interactions between the level-of-

⁸ We are grateful to an anonymous referee for having pointed this out to us.

⁹ The null hypothesis of equality of the travel time coefficients under severe congestion versus low/moderate congestion produced a t-test value of 0.472 (for a model estimated with the full sample), 0.51 (for the model for frequent drivers) and 1.69 (for the model for occasional drivers), allowing accepting H_0 at the 95% confidence level.

service attributes and the different characteristics (i.e. sex, age, education level, trip purpose, type of driver) of the respondents (Ortúzar and Willumsen, 2011, p. 279). However, results were not statistically significant so they were finally excluded from the model.

Table 5 summarise the results of Model 1 and a second one, Model 2, setting all parameters as random variables, distributing Normal¹⁰ with mean and standard deviation to be estimated, and considering a common error component which distribute i.i.d Normal (0, σ) across individuals, but remained constant within all responses from a given individual to account for the panel effect (Walker *et al.*, 2007); for estimation we used Biogeme (Bierlaire, 2003) and 2000 Halton draws.

Model 2 shows a substantial gain in goodness of fit, easily allowing to reject the null hypothesis of model equivalence with the first. We found random heterogeneity in all parameters (the standard deviation - *std dev* - of their Normal distributions are statistically significant at the 95% confidence level). The low *std dev* of the time parameter implies a very low likelihood of positive values, which is a good result (for a discussion, see Sillano and Ortúzar, 2005).

For the remaining parameters, their distributions would fall mostly in the negative region: 10% of respondents would be expected to have a fatalities' parameter greater than zero, and the equivalent figure would be 11%, 13% and 18%, respectively for the cost, seriously injured and pedestrian victims' parameters. Previous work has shown that if individual parameters are estimated, the actual number of individuals with a wrong sign tend to be less than expected and, more importantly, the actual parameter values are not significantly different from zero (Sillano and Ortúzar, 2005).

Regarding the mean of the ASC for the current route, its positive value implies an inertia effect suggesting the presence of a certain reluctance to change. Moreover, the SQ parameter varies over respondents and the distribution falls mostly in the positive region.

The absolute value of the mean coefficients of the risk variables imply that the death rate equivalence of a serious injury (i.e. the ratio between the coefficient of seriously injured car occupants and the coefficient of car occupants' fatalities) is 0.17. The equivalent ratio for the pedestrian victims' coefficient is 0.33.

¹⁰ The true distribution of each random parameters is obviously unknown; so, in principle, any distribution could be applied (Carlsson *et al.*, 2003; Hensher and Greene, 2003). We chose the Normal because it is the most easily applied distribution (Train and Sonnier, 2005).

Table 5. Results from the estimated models

	Model 1		Model 2	
Attributes	Coefficient	t-test	Coefficient	t-test
Actual Route ASC				
<i>Mean</i>	0.197	5.19	0.577	5.82
<i>Std Dev.</i>			1.02	6.79
Travel time				
<i>Mean</i>	-0.0442	-8.81	-0.132	-9.15
<i>Std Dev.</i>			0.015	0.6
Cost				
<i>Mean</i>	-0.553	-14.9	-1.85	-11.14
<i>Std Dev</i>			1.53	9.73
Seriously injured				
<i>Mean</i>	-0.122	-23.45	-0.295	-11.65
<i>Std Dev.</i>			0.268	9.22
Fatalities				
<i>Mean</i>	-0.714	-28.61	-1.71	-13.69
<i>Std Dev.</i>			1.34	9.37
Pedestrian victims				
<i>Mean</i>	-0.24	-4.92	-0.572	-5.06
<i>Std Dev.</i>			0.627	4.14
σ Panel			0.274	2.20
Log-likelihood (C)	-2964.82		-2964.823	
Final log-likelihood	-2191.57		-2046.674	
Adjusted rho-squared	0.261		0.308	
Number of observations	4291		4291	
Number of Halton draws	-		2000	

The last coefficient reflects drivers' preferences to reduce the risk of pedestrians, so we are not dealing with pedestrian preferences. As discussed above, it is impossible to determine if this coefficient is a reflection of altruistic preferences (contributing to the safety of third parties) or selfish preferences (avoiding the psychological, economic and legal costs associated with hitting and injuring a pedestrian). In addition, note that this coefficient comprises both a marginal disutility

of seriously injured pedestrians and a marginal disutility of pedestrian fatalities. This latter fact plays a key role in the calculation of the value of risk reductions for pedestrians, as shown below.

5 ESTIMATION OF WILLINGNESS TO PAY VALUES

Table 6 shows the subjective values of travel time savings, together with the WTP for all risk reductions derived from Model 2. As the model specification includes Normal distributed parameters, the WTP measures are random variables with an unknown distribution. Therefore, we used simulation to estimate these values (Roman *et al.*, 2005). To obtain plausible values, the distribution of both numerator and denominator of the WTP expression were truncated to values with consistent marginal utility (i.e. with an appropriate sign)¹¹. Further, as the mean could be highly affected by the presence of undesirable outliers (the denominator of the WTP may take values near zero), the median of the distributions was computed as it was deemed more appropriate in our case.

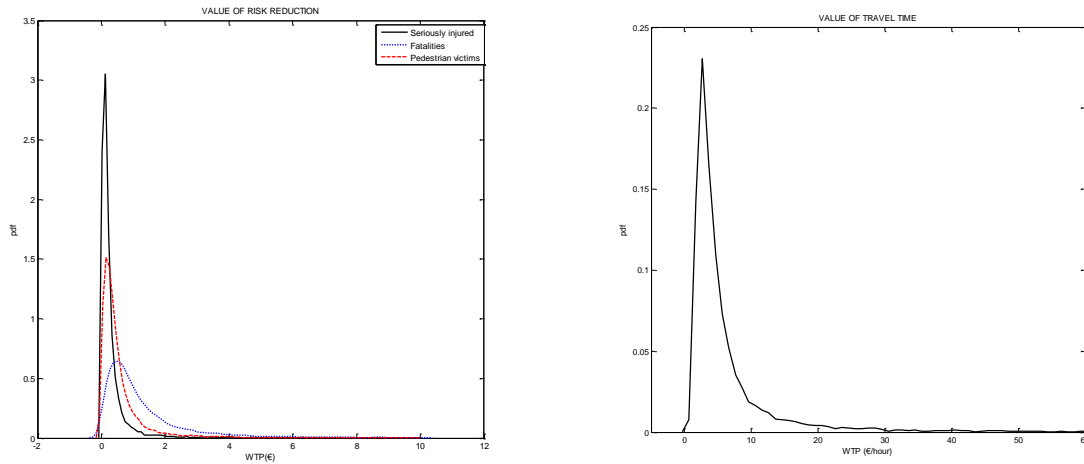
Table 6. Estimated willingness to pay values

		Ratio of means	Median
Subjective value of travel time (€/hour)		4.3	3.9
WTP to reduce risk of accidents (€/trip)	Seriously injured	0.16	0.17
	Fatalities	0.93	0.89
	Pedestrian victims	0.07	0.35

To provide more information and compare differences among WTP distributions, the kernel density plots of the simulated distributions are presented in Figure 2. We observe that the distributions of the WTP to reduce the risk of accidents involving pedestrian victims and fatalities present a higher degree of dispersion.

¹¹ The mean of the simulated distribution was computed over values of the WTP less than 10 euros.

Figure 2. WTP distributions



The values of travel time according to the median are consistent with recent values estimated in the Canary Islands by Grisolia and Ortúzar (2010) in the context of interisland travel and by Grisolia *et al.* (2015) in the context of a SCE related with determining the acceptance of a congestion pricing scheme in the city of Las Palmas de Gran Canaria¹². Notwithstanding, the values appear rather low in comparison with previous Spanish empirical evidence, in particular the figures obtained by Espino *et al.* (2006) and by Cantos and Alvarez (2009) for total travel time, albeit in another context.

A possible further explanation for obtaining relatively low values of time lies in the fact that although the highway under study is 55.6 km long, the majority of trips concentrated around the metropolitan area (with average trip lengths of less than 20 km). Thus, we are dealing with short trips where time is probably considered relatively less important than variables related with road safety. In addition, an important number of drivers (60%) did not experience severe congestion in our sample; this, together with the short travel distance, could mean that the travel time variations presented in the hypothetical choice scenarios were given less importance than the variations in other route attributes. A final plausible explanation, mentioned in previous studies, is the fact that there are more risk attributes than time attributes (Weber *et al.*, 1988).

¹² In Spain, the *Manual de Evaluación Económica de Proyectos de Transporte* (2010), established a unit value of travel time between 8.30 and 9.90 €/hour for non-commuters and commuters travelling by car in short distances in Spain. However, lower values for travel time in Tenerife could be expected as its *per capita* income level is one of the lowest in Spain.

To obtain the values of risk reductions, the WTP for all drivers in the highway must be added. However, the actual number of annual trips taking place on route TF5 is unknown and vehicle counts are only available at some selected stations. We were able to estimate the number of km driven per vehicle using the following approach. Since the entries and exits to highway TF5 did not coincide with the counting stations on the route, we could not assume that all vehicles counted at a given station completed the entire trip until the next station. Hence, if we take the total number of vehicle-km driven under the assumption that entries and exits coincide with the counting stations as starting point, we must apply a coefficient (less than one) to correct for the over-estimation. As a result, we assumed that the number of vehicles that completed the trip until the next station was inversely proportional to the distance between both stations. This is based on the assumption that the longer the distance, the higher the probability of leaving the road at an intermediate point.

Moreover, the average distance travelled by drivers on route TF5 is also unknown. Nevertheless, although this value cannot be obtained exactly for the drivers in our sample, since highway entry and exit points were grouped by proximity considerations, it is possible to approximate the distance travelled by geo-referencing their declared points of entry and egress to/from the highway and calculate the distance between both points. In this way we estimated that the average trip of drivers in the sample was 17.8 km.

These assumptions led us to obtain that the annual traffic in route TF5 was 11.89 million trips (see Appendix 1), given an average trip distance of 17.8 km¹³, and to estimate the values of risk reductions for the various risks shown in Table 7.

Table 7. Values of risk reduction for car drivers

Value of risk reduction for:	millions €
Car-users seriously injured (VSRR)	2.00
Car-users fatalities (VFRR)	10.63
Pedestrian victims (VPRR)	4.21

¹³ Combining this information with the average annual number of fatalities for car users (drivers and passengers) from Table 2, we can estimate the risk of being fatally wounded in a road accident in the TF5 highway as one fatality per 42.3 million vehicle-km; or equivalently as 2.36 fatalities per 100 million vehicle-km. Thus, if one fatality is reduced, risk is reduced by $4.7 \cdot 10^{-9}$.

The *VFRR* value of € 10.63 million is relatively high in comparison to previous values reported in the literature. In particular, De Blaeij *et al.* (2003) summarized the results of 29 studies carried out in the US, Europe and New Zealand. Eleven of these provided specific values, 17 also provided confidence intervals and only one reported a point estimate derived from a stated preference survey and a confidence interval derived from a contingent valuation survey. Taking all point estimates reported plus the two values associated to confidence intervals (lower limit and upper limit), they total 48 values. Three of the 48 reported values were in the € 20 million to € 30 million range; three more in the € 10 million to € 20 million range; 31, in the € 1 million to € 10 million range, and the remaining values were all below € 1 million¹⁴. So our point estimate ranks fairly high.

There is also a large meta-analysis by Lindhjem *et al.* (2011) on the value of the statistical life regarding transport, health and air pollution studies. Our point estimate is 31% higher than their mean estimate of € 7 million¹⁵.

In Spain we are aware of only two stated preference studies concerning the value of a statistical life in the transport sector¹⁶, but none of them was based on stated choice experiments. Martínez *et al.* (2007) used the contingent valuation method in the context of traffic accidents to estimate the value of preventing a fatality, obtaining values starting at € 2.7 million. More recently, and developed simultaneously with this study, Abellán *et al.* (2011), used a sample of 2,020 observations and a method known as “contingent valuation (CV)/standard gamble (SG) chained approach” (Carthy *et al.*, 1999), to obtain that the total value of preventing a road fatality in Spain would amount to €1.4 million.

¹⁴ The values reported by De Blaeij *et al.* (2003) are in 1997 US\$. They were updated to 2010 US\$ values (36% increase in CPI, according to <http://www.minneapolisfed.org/>) and converted to € using an exchange rate of € 1 = US\$ 1.3138 (http://www.federalreserve.gov/releases/h10/Hist/dat00_eu.htm).

¹⁵ The Lindhjem *et al.* (2011) values were reported in US\$ from 2005. We updated them to 2010 and converted that value to 2010 € using the figures in footnote 14.

¹⁶ Although there is additional evidence for the value of a statistical life in Spain, it refers to studies carried out in sectors other than transport; for example, estimates were obtained on the basis of correlating the risk of a fatal working accident and the observed workers' salary. In these studies, the value of a statistical life varied between 2.6 and 3.9 million € for the year 2010 (Albert and Malo, 1995).

Although a comparison with the available literature suggests that our values are not implausible, we decided to carry out a thorough analysis of the possible reasons for the high values found in our study. Firstly, we note that some respondents may have underestimated their travel costs, since it is not easy to compute operating travel costs and they did not require meeting an immediate out-of-pocket expense in this highway.

Secondly, the drivers in our survey may have placed an excessive emphasis on the importance of accidents when completing the questionnaire, at the expense of valuing less their travel time savings. In fact, respondents seemed very concerned about their safety; the relatively high number of potentially lexicographic respondents (23% of the total) regarding the attribute 'fatalities' points in this direction. Thus, there is a chance that some of them may have answered strategically and picked up the safest route in terms of fatalities in every choice scenario.

Thirdly, there is no reliable estimate of driven kilometers nor of the average distance of a trip on route TF5 and this could create an 'error in variables' problem. If the average distance was different, the values shown in Table 7 would change. As a sensitivity analysis, all the estimated values are inversely proportional to the average distance; therefore, if this was double, all estimated values would halve and vice versa.

As a final comment, it is important to point out that in all stated preference methods individuals may present a tendency to underestimate the influence of price in their choices, as they do not have to pay it. If this were the case, the WTP would show a rising systematic bias and it would be desirable to apply correction factors. Unfortunately, it is not clear what this factor should be. On the other hand, it is likely that the ratios of the WTP for different road safety attributes are less affected by such hypothetical bias (Goett *et al.* 2000) and, thus, these ratios could be considered as the most reliable result of our study.

With respect to the value of avoiding severe road injuries, this is around 18% of the value of avoiding a fatality. This proportion is in line with reported values by INFRAS/IWW (2000), Persson *et al.* (2001), Persson (2004), Svensson (2009) and Veisten *et al.* (2013), and somewhat higher than the 9% value reported by Jones-Lee *et al.* (1995).

The value of reducing a pedestrian casualty is the drivers' willingness to pay to reduce the risk that a pedestrian suffers a fatal or serious injury (*VPRR*). We estimate this value as roughly 39% of the value of drivers' willingness to pay for reducing their own risk of death. From this figure, both the value of reducing a fatality and a serious injury to pedestrians (*VRPF* and *VRPSI*)

respectively) may be derived, if we assume that these two values are proportionate among them. If we consider the proportionality found in this study (i.e., 17%), following a formula developed by Hultkrantz *et al.* (2006), we can calculate the above values as:

$$VRPF = \frac{VPRR}{DRE_{SI} \cdot \text{delta } si + \text{delta } f} \quad (9)$$

where DRE_{SI} : *death-risk equivalence*, which equals the relative value of preventing a serious injury with respect to preventing a fatality (Jones-Lee *et al.*, 1995; Viscusi *et al.*, 1991), that is: $DRE_{SI} = VRPSI/VRPF = (0.16)$; *delta si* and *delta f* represent, respectively, the actual shares of serious injuries and fatalities in car accidents where pedestrians are hit. Given that the observed average values for these shares in route TF5 in the 2006-2008 period were 0.33 and 0.67, respectively, the abovementioned decomposition can be made.

Considering our valuations ($VPRR = € 4.21$ million), the $VRPF$ would be € 5.62 million and the $VRPSI$ € 0.89 million. These figures imply that the value of reducing a pedestrian fatality and a pedestrian injury are equal to 52 and 46 %, respectively, of the value of reducing a car occupant fatality and a car occupant severe injured for car drivers. Despite not having a reference point against which to compare these values, these results are in line with our expectations: car drivers value significantly less the avoidance of pedestrian casualties compared to car occupants' casualties. We were expecting this result because, for respondents, both their car companions and themselves are 'known persons' compared to pedestrians who are not-known third parties with no emotional ties. As an aside, this result suggests that car design improvements that are pedestrian friendly may be welcome by car users, as there is a positive willingness to pay to avoid the risk of running into a pedestrian and injuring her.

6 CONCLUSIONS

Estimates for the value of a statistical life computed from stated choice experiments do not exist in Spain. To our knowledge, the only studies vaguely resembling this one are Albert and Malo (1995), who analysed revealed preference data (hedonic wages), Martínez *et al.* (2007), who used the contingent valuation method, and Abellán *et al.* (2011), who used the contingent valuation/standard gamble chained approach. As such, this study is the first attempt to establish a value for a statistical life in Spain using stated choice data for a route choice context including road safety attributes. The values of statistical life estimated in this paper provide a basis for the evaluation of road safety interventions in cost-benefit analysis.

Specifically, we estimated a series of discrete choice models considering the following independent variables: travel time, risk of accidents, risk of killing/seriously hurting a pedestrian and travel operating costs. The risk of accidents was introduced by means of two variables, the expected number of car-users deaths in a year and the expected number of seriously injured car-users in a year. Mixed logit models incorporating random parameters and panel correlation effects were estimated, where one of the alternatives (*status quo*) was always the route currently used by the respondent and the second was a hypothetical alternative route. The estimated models were completely satisfactory from the statistical point of view, with significant coefficients showing the expected sign. An inertia effect towards choosing the current route was detected, which may be interpreted as a measure of reluctance to change.

The point estimate benefit of reducing a car occupant fatality was estimated in € 10.23 million, a value that is somewhat high in relation to point estimate values reported in the literature but well within their confidence intervals. The value of reducing a serious injury is around 17% of the value of reducing a fatality, a proportion well in line with reported values in previous international studies. For example, in Sweden, Svensson (2009) calculated this ratio as 15-16 %; while in Norway Veisten *et al.* (2013) estimated it as about 20%.

An important contribution of this study is the estimation of a value for reducing a pedestrian casualty, a new result in the literature up to our knowledge. This value came up as 39% of the value of reducing a car occupant fatality.

As discussed in section 3, a caveat should be in place when interpreting WTP results for road safety improvements. These values may include components over and above personal safety: altruistic safety, the horror of witnessing the scene of a car accident with casualties, the costs of traffic disruption of accidents and, in the case of pedestrian casualties, an own risk component if the driver herself is a pedestrian on the TF5 route. The survey carried out does not allow us to disentangle these components.

Finally, we wish to stress there are several interesting aspects that go beyond the scope of this paper but deserve attention in future research. One is to identify different profiles of drivers with different preferences, using latent variables or latent class models. Another relates to the use of hybrid choice models, accounting for asymmetric preference formation in willingness to pay or for the effects of learning and fatigue. Finally, we could even use WTP space models to better characterize the distribution of the willingness to pay among the population.

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APPENDIX 1: Proposed Choice Situations for the SC Experiment

Attributes		Choices								
		1	2	3	4	5	6	7	8	9
Current route	Travel cost	C	C	C	C	C	C	C	C	C
	Travel time under severe congestion	T ₁	T ₁	T ₁	T ₁	T ₁	T ₁	T ₁	T ₁	T ₁
	Travel time for low/moderate congestion	T ₂	T ₂	T ₂	T ₂	T ₂	T ₂	T ₂	T ₂	T ₂
	Car-users deaths/year in route TF-5	5	5	5	5	5	5	5	5	5
	Severe car-users injuries/year in route TF-5	32	32	32	32	32	32	32	32	32
	Pedestrian victims/year in route TF-5	3	3	3	3	3	3	3	3	3
Alternate route	Travel cost	C-50%	C	C+50%	C+50%	C	C-50%	C-50%	C	C+50%
	Travel time under severe congestion	T ₁ -25%	T ₁ -25%	T ₁ +50%	T ₁ -25%	T ₁	T ₁ +50%	T ₁ +50%	T ₁	T ₁
	Travel time for low/moderate congestion	T ₂ -25%	T ₂ +25%	T ₂	T ₂ +25%	T ₂	T ₂ -25%	T ₂ +25%	T ₂	T ₂ -25%
	Car-users deaths/year in route TF-5	7	5	5	5	3	3	7	3	7
	Severe car-users injuries/year in route TF-5	32	22	22	42	42	42	32	22	32
	Pedestrian victims/year in route TF-5 F-5	3	2	2	4	2	4	3	4	3

APPENDIX 2: Calculation of Kilometres Driven

Vehicle Counts						
Km	Number of vehicles			Km travelled		
	Going up	Going down	Total	Going up	Going down	Total
0	27 290	830	28 120	39 297.6	1 195.2	40 492.8
1.44	52 867	49 584	102 451	37 536	35 205	72 740
2.15	63 766	56 004	119 770	303 526	266 579	570 105
6.91	63 302	52 245	115 547	141 163	116 506	257 670
9.14	51 826	63 574	115 400	171 026	209 794	380 820
12.4	43 089	42 478	85 567	389 955	384 426	774 381
4						
21.4	34 330	33 315	67 645	386 556	375 127	761 683
9						
32.7	31 722	33 843	65 565	205 559	219 303	424 861
5						
39.2	13 428	13 769	27 197	2 686	2 754	5 439
3						
39.4	14 030	14 224	28 254	100 595	101 986	202 581
3						
46.6	24 488	1 076	25 564	66 852	2 937	69 790
49.3	12 721	12 293	25 014	42 107	40 690	82 796
3						
52.6	7 357	13 416	20 773	2 281	4 159	6 440
4						
52.9	6 693	7 028	13 721	18 406	19 327	37 733
5						

In each row, a marker along the TF-5 indicates where the vehicle estimated entry or exit station is located.

Source: Cabildo Insular de Tenerife

The above table displays information about registered vehicles expressed as a daily annual average traffic. Under the assumption that the entries and exits of vehicles on the TF5 coincide with sites with vehicle estimates, the calculation of vehicle-km would be exact and equal to 3,687,532. Considering an average distance of 17.8 km per trip and assuming that traffic is 30% of a regular day during weekends, we obtain that the total annual traffic would be 11,894,887 trips, under the assumption that the number of vehicles that complete the trip until the next station is inversely proportional to the distance between both stations.

These figures could seem contradictory since the total trips are less than those reported at some stations. However, these stations are located in urban areas where many vehicles use the TF5 for very short routes. If these drivers follow a path that does not belong to the TF5, adding their WTP would imply unrealistic increases in the calculation of the value of statistical life.